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San Francisco, California
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To: Regional Forester, R-5
Forest Supervisor, Cleveland

From: Willis W. Wagener, Senior Pathologist,
Div. of Forest Pathology

Subject: Relation of Fungi to Pine Killing, Laguna Mountains Recreational Area, Cleveland N. F.

In his report of May 22, 1941 entitled "Some biological considerations of the 1940-1941 Mt. Laguna Recreational Area control job" Associate Entomologist Donald DeLeon of the Berkeley Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine, called attention to the presence of a rot fungus associated with many of the trees treated for insects on the Laguna area during the 1940-41 season and noted that in places the killing appeared to have progressed from a central focus causing circular openings in the stand. He concluded that "until a thorough study is made of the relations of the root-fungus to the presence of insect infested trees no satisfactory program for the prosecution of insect control work can be drawn up" for the area.

Late in October the writer, C. E. Dunston of the R-5 Branch of Timber Management and Supervisor Norman Farrell and Ranger V. C. DeLapp of the Cleveland joined Senior Entomologist J. M. Miller and Associate Entomologist DeLeon of the Berkeley Insect Laboratory in a field examination of representative recently dead trees on the Laguna area. Following the departure of the other representatives the examination was continued by the writer for two additional days and specimen material was collected for further laboratory study. This amount of field time was not sufficient to permit a detailed appraisal of all factors entering into the killing but it is believed that enough was learned to aid materially in an understanding of the immediate causes for a good part of the dying that has occurred in recent years.

Root killing by Fomes annosus. All the evidence indicates that this fungus is an active root pathogen in the Lagunas and may have been the primary agent for an estimated 70 per cent of the jeffrey pine killing that has occurred there in the last few years. Trees of all ages and sizes may be attacked. The fungus works from central foci,

often causing group killing and in time producing openings in the stand similar to that shown in Figure 2 of Dr. DeLeon's report and Figures 1 and 2 of this memorandum.

The fungus apparently spreads from one root system to another under ground. Killing is a relatively gradual process, often preceded by the formation of zones of resin infiltration in portions of the attacked roots or of abnormal resin ducts in the outer sapwood at the base of the tree. The fungus forms a thin whitish mycelial-layer between the bark and wood of killed roots or root crowns and thin wefts of mycelium may also be produced in crevices or openings in the bark below ground level. Fruit-bodies of the fungus do not appear to be common on the Lagunas and those that were found were on small trees only an inch or two in diameter. One of these, on a still living jeffrey pine seedling about 5 feet in height is shown in Fig's 3 and 4. The fruit-bodies form under the duff at ground level and are not evident until the duff layer is removed.

The first fruit-body found associated with killed trees on the Lagunas was collected on July 10, 1941 by Dr. DeLeon and was referred by him to this office but because it occurred on a tree that had been dead for several months the connection with the killing could not be definitively postulated. Additional specimens found last fall, however, both on recently killed and living trees in groups around typical foci left little doubt of the connection of the fungus with the root killing though this has not yet been positively confirmed by the artificial inoculation of healthy trees.

Affected living trees which were found in the course of the fall examination almost invariably showed some evidence of distress, varying from general thin foliage to abnormally short 1941 needle growth and the premature dying of the older needles. An example of shortened 1941 needle growth on an affected 4" d.b.h. jeffrey pine is shown in Figure 5. To what extent it will be possible to recognize attacked trees prior to their death, particularly at seasons of the year other than fall or early spring, is not certain but most of those around established foci should be recognizable.

The following brief descriptions of typical groups where Fomes annosus was found to be active may serve to illustrate the current role of the fungus in the Laguna area:

Group 1. Near Desert Rim road back of Burnt Rancheria Campground. 7 jeffrey pines 1-14 inches d.b.h. dead 1941, 6 dead earlier, some several years ago. Also several small seedlings dead 1941 or earlier. Killed trees in strip down hill rather than

in circle. Small tree just dying has F. annosus mycelium on roots. Living 5' jeffrey pine seedling shows annosus mycelium on roots and fruit-body around stem at ground level under duff. Similar fruit-body at base of small dead tree.

Group 3. South of Burnt Rancheria Campground near highway, 2 jeffrey pines, 7" and 4" d.b.h., dead 1941, at least 3 trees dead earlier. 4" d.b.h. living tree near similar sized dead one has very short 1941 growth and F. annosus mycelium is present on roots. Also 5" and 26" d.b.h. trees with thin foliage and fungus mycelium on part of roots. Several dead seedlings.

Group 10. (Fig. 2). On private land below F. S. Recreational Area, 6 jeffrey pines, 4"-16" d.b.h. dead 1941, all with F. annosus mycelium on roots. No bark beetles in the lower boles of 2. Two more trees sickly and will probably die in 1942. 49 stumps in strip-like opening down hill, representing trees previously treated for insects, mostly within the last 2-3 years. Another group, nearly contiguous, with 4 trees dead 1941, two dying and 47 stumps present.

Killing by Armillaria mellea. This fungus is well known as a killer of orchard trees and ornamentals in California but occurs much less commonly on pines and then usually on sugar pine. Several locations in which the fungus had unquestionably been responsible for the death of jeffrey pines were found on the Laguna area, however, (Fig's 6 and 7) and Dr. DeLoon cited other cases in his report of last May. While the fungus is thus a factor in the pine killing on the area it appears to be much less important than Fomes annosus and is probably responsible for less than 10 per cent of the dying. In all but one of the locations the killed pines were in the vicinity of decadent or dead oaks, with which the fungus is so frequently associated that the common name "oak-root fungus" has long been applied. In the single case found where no oak was in the vicinity the trees were located near the highway right-of-way where an oak may well have been removed in the course of highway construction.

Pines attacked by Armillaria not only showed the characteristic mycelial felts of the fungus under the bark (Fig. 6) but clusters of the mushroom-like fruit-bodies were found around the bases of 3 pines that had died in 1941. Progressive killing results in openings in the stand though no instance of this was found where as many trees appeared to have been killed as in some of the openings resulting from the action of Fomes annosus.

Dying from other causes. Excavations were made around the bases of several recently dead trees or groups of trees where no signs of either Fomes or Armillaria could be found. At one location where an examination was made of a group located by the entomologists there was evidence of progressive group dying without any evident associated fungus and no insects that the entomologists considered to be ordinarily responsible for killing of this sort, if my impression of

their judgment in the matter was correct. The relative proportion of killed trees in this class, for which the cause of death can not yet be satisfactorily ascribed, is not large, judged on the basis of the number of cases of this sort found last fall, but might become greater at other periods.

A few trees were noted where infestation by the pine mistletoe, Arceuthobium campylopodum was so heavy that its effects, in combination with the work of the species of Cylindrocopturus reported to be associated with mistletoe by Dr. DeLeon in his report of May 22, seemed to be the principal cause for death. In the few cases of this sort that were found the trees were small and badly deformed so that their loss was not especially serious.

The premature killing of needles older than those of the current season in localized areas, usually of less than an acre in extent, was noticeable in places through the pine stand. Affected needles, when examined in the laboratory, showed no specific needle disease of fungous origin but appeared to be infested with a scale insect near the base, with accompanying resin infiltration of the needle tissues at that point. On the basis of material submitted to the Berkeley Insect Laboratory, Junior Entomologist H. L. McKenzie has identified the scale as a species of Matsucoccus, resembling in habit Matsucoccus fasciculensis, common on jeffrey pine in parts of California. In the infested areas on the Lagunas a pronounced reduction in living foliage had been brought about which might well make the affected trees more susceptible to killing by other agencies even though not in itself severe enough to cause death directly.

Status of root diseases. The root disease conditions evidently existing in the Laguna Area as indicated by the examination are of more than ordinary interest because of the differences they present from anything hitherto reported from other places. Fomes annosus is the cause of a common root rot and butt rot of conifers and occasionally of broad-leaved trees in Europe but occurs principally on ecologically unfavorable sites or in unnatural pure stands such as those resulting from planting. In North America the fungus is widely distributed but is regarded as of much less importance than in Europe and either occurs as a butt rot in the heartwood of the lower trunk or as a weak parasite causing a root rot of weakened trees. In Europe it is more commonly associated with highly acid soils, soils with a high water table for part of the year or crowded pure coniferous stands, particularly those resulting from planting on soil formerly under cultivation or those in which conditions favor the formation of a thick layer of raw humus over the soil surface.

On the Lagunas none of these conditions are present. Instead, the stand is a natural one, quite open in character, the soil is loose, the drainage excellent and the growth rate relatively good. The reason for the apparent virulence of the fungus is therefore somewhat obscure. It would

appear either that there are other features of the environment than those commonly associated with attacks by the fungus elsewhere that favor it on the Lagunas or else an especially virulent form or strain of the fungus has developed there.

Control. From the field evidence it would appear that Fomes annosus is the organism most in need of control if a real reduction in the dying of trees on the Laguna Area is to be achieved. Because of the differences in conditions, methods recommended for control of the fungus in Europe are for the most part inapplicable on the Cleveland. The measure suggesting itself as most likely to reduce killing by the root pathogen is the pulling of affected trees around attack foci either before they are killed or soon enough afterward to accomplish the removal of the roots before they become decayed.

Under the measures followed in the past, of cutting killed trees and burning or peeling them to destroy bark beetles, the stumps that have been left have furnished excellent material for the perpetuation of the fungus, which by nature is not only a pathogen but also a decaying organism acting saprophytically to destroy dead wood. It is not known how long the fungus remains active in these roots and stumps but probably for several years, during which time the overlapping root systems of adjacent living trees are constantly exposed to infection.

The very friable nature of the soil on the Lagunas and the relatively small size of most of the attacked trees should facilitate pulling, either with a stump puller or by the use of a tractor. Since the object of the pulling would be to extract the roots in as nearly an intact form as possible it should be done at a time of the year when the soil will yield the most readily and if possible the form of power used should be the one that would cause the least breaking or tearing of the roots in getting them out. Spring or fall would probably be the most suitable periods, from all aspects, for doing the pulling, as the ground would be likely to be in a favorable condition then and the slash could be burned. Burning of the diseased roots and stumps would probably not be essential, since the fungus loses its viability rather soon in wood that is allowed to dry out, but is considered desirable.

Under prevailing war conditions it will probably not be possible to pull all annosus trees on the Lagunas but we believe it important that a sufficient number should be pulled to determine how effective this method of control will prove to be. In other words the measures to be undertaken now are to be considered experimental but they should be carried out if at all possible in order that information on their effectiveness will be available when conditions make full scale control operations practicable. In the meantime, also, further study of

conditions on the area should be made to more definitely establish the relative roles of the different organisms and insects active there and to throw more light on the reasons for the death of trees where causes at present are still obscure.

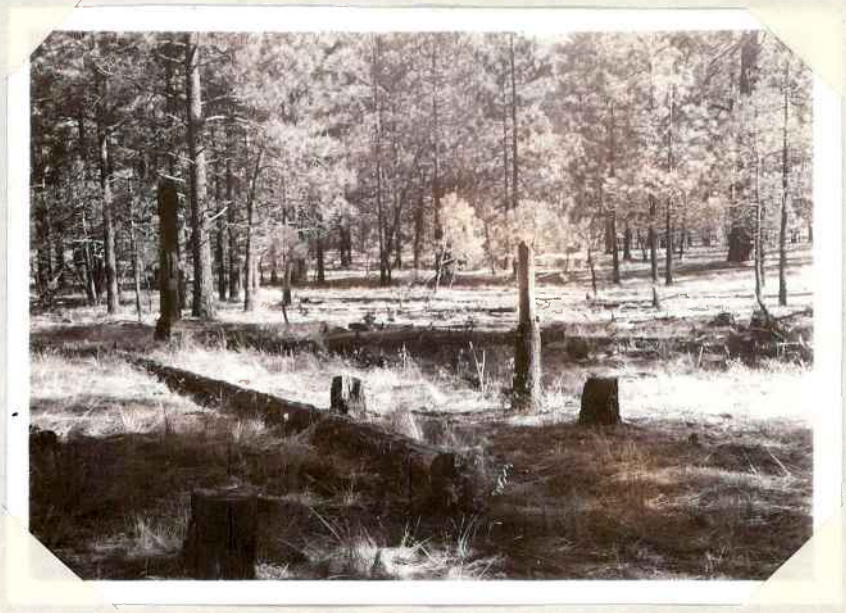

Fig. 1. Opening in jeffrey pine stand from progressive killing. Two trees around this opening died in 1941 and another was dying. Fomes annosus was found on roots of all 3. Stumps or remains of 38 previously killed trees are present in the opening.

Fig. 2. View down a hillside strip in jeffrey pine in which Fomes annosus has been active. The 6 blazed trees died in 1941. Two of them had not been invaded by bark beetles. Two additional trees in the group, not marked in the picture, were sickly, with Fomes annosus mycelium on the roots.

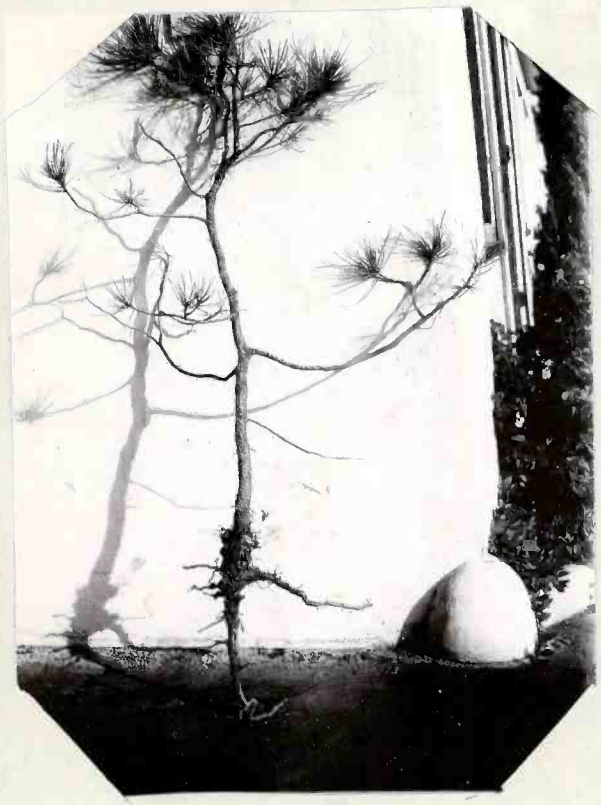

Fig. 3. Fomes annosus fruit-body at the base of a 6 foot living jeffrey pine. The main root has been killed and the rest are affected. 1941 needles were short. The tree would probably have died early in 1942.

Fig. 4. A close-up of the Fomes annosus fruit-body shown in Fig. 3. The fruiting body developed at ground level under the duff and was not visible until the duff had been scraped away.

Fig. 5. Twig from living 4" d.b.h. jeffrey pine attacked by Fomes annosus showing short 1941 growth. The tree is expected to die in 1942.

Fig. 6. White hyphal felts of Armillaria mellea under bark of 8" d.b.h. recently killed jeffrey pine. The felts extend to more than 4 feet above ground.

Fig. 7. Opening in young jeffrey pine around decadent oak. The 2 pines to the right of the oak in the photograph died in 1941 and were producing abundant Armillaria mellea fruiting bodies at the base.